SOME LESSONS FROM THE STUDY OF ARTERIAL PRESSURE.[1]

By G. A. Gibson, M.D., F.R.C.P.Ed., *Physician to the Royal Infirmary, Edinburgh.*

My contribution to the discussion on blood pressure at the Annual Meeting of the British Medical Association at Toronto was, by request, limited to the consideration of clinical methods, and the results obtained by such methods were dealt with by subsequent speakers in the debate. But it seemed to me quite necessary to point out the factors upon which the pressure of the blood depends, and on this occasion, in appearing before you in response to the kind invitation with which you have honoured me, you will permit me briefly to mention by way of preface the considerations which were then advanced.

The blood pressure is primarily due to the cardiac energy, as shown by amount of outflow and velocity of expulsion. All the cardiac functions—rhythmicity, excitability, contractility, conductivity, and tonicity—are certainly engaged. The intrinsic energy of the heart is subject to extrinsic conditions, *e.g.*, the amount of blood reaching it from the great veins, and the resistance which it has to overcome. Increased rate, with free access of blood, as a rule raises the pressure, and *vice versa*; yet in such

[1] The Address at the Annual Meeting of the Sunderland Division of the North of England Branch of the British Medical Association.

a condition as heart-block with bradycardia the arterial pressure may be nearly 300 mm. Hg. Any lessening of the afferent blood lowers the pressure; every increase in resistance up to a certain level raises it. If the resistance, however, is too high, the outflow is reduced and the pressure falls. The cardiac energy may be modified by the influence of the augmenting and inhibiting nerves. By means of the nervous mechanism, moreover, the heart is automatically relieved from the effects of overwork. As regards the action of the heart, then, we may conclude that any increase in the outflow from the ventricles raises the blood pressure, when the other factors are constant, and, conversely, a diminution produces a fall. This may perhaps be due to increased velocity, caused by the action of the augmentor nerves without any acceleration of rate.

The peripheral resistance has great importance in maintaining the arterial pressure, and this is found to depend on several causes. The tone of the blood vessels is the most powerful factor in this connection. The general tone is due to a balance between the influence of the vaso-constrictor and vaso-dilator nerves, but, as the latter are not continuously in action, they may be disregarded. Time forbids my dwelling upon the subject, but you will allow me simply to recall the well-known fact that if the tone of the blood vessels is seriously lowered, there is more or less complete venous stasis, and greater or less failure of the circulation from lack of blood reaching the heart. The tone of the blood vessels presents general and local variation. The general pressure responds to the general tone throughout the entire circulation, but the local pressure undergoes great changes in accordance with special requirements. The most remarkable facts bearing out this statement are derived from the abdominal vessels under the influence of the splanchnic nerves. An increase of function in any particular area produces an increased blood supply through the action of the vaso-dilator nerves, leading to dilatation of the smaller arteries. Conversely, cessation of function in any part is at once followed by the resumption of the normal tone exerted by the vaso-constrictor nerves. Further, it has been proved that the general as well as the local blood pressure is subject to reflex influences arising even in distant parts. To sum up this part of the subject, we may say that, other factors being constant, increased resistance is associated with higher, and lessened resistance with lower, pressure.

Vascular elasticity is of great importance. By means of it the energy of the heart is transferred to the vessel walls in the form of potential, continuously becoming kinetic, energy; in this way the onward movement of the blood is subject to a much more continuous influence than if it were solely dependent upon the intermittent energy of the heart. When the structure of the blood vessels is intact, they possess extremely wide limits of

elasticity, meaning that their walls can return to normal after great distension. When this wide limit of elasticity is lessened by morbid changes, there is an increased resistance to the blood flow, and at the same time a tendency to distension of the vessels.

The amount of blood in circulation must be of some importance in regard to arterial pressure, but it has less influence than the factors which have just been considered. The comparatively slight effect of changes in the contents of the vessels is obviously due to the fact that variations in the amount of blood speedily bring about compensatory alterations in the tone of the blood vessels, so that they adapt themselves to the quantity they contain, and restore the pressure to the normal for the conditions which are present. Our knowledge of this subject is chiefly the result of experimental physiology, at least as regards additions to the amount of blood in circulation. Physiological researches on the effects of reduction of the amount are borne out by observations upon cases of severe hæmorrhage in practice. The data obtained from both sources of information lead us to the conclusion that changes in the volume of the blood only produce transient effects on arterial pressure.

The viscosity of the blood is another factor which undoubtedly has some importance; the amount of weight to be attached to this influence is at present largely a matter of speculation. As there is always a layer of blood, more or less stationary, in contact with the walls of the blood vessels, the viscosity is probably not very important.

The Toronto discussion was remarkable, amongst other aspects, for the sharp divergence of opinion between some of us as regards the value of digital palpation of the pulse: Sir William Broadbent stoutly asserted that the pressure of the pulse could be more satisfactorily ascertained by means of the educated finger than by the use of any of our modern instruments, while it was my solemn duty, on the other hand, to confess quite frankly that thirty years' experience had taught me how extremely fallacious this method is. It is undoubtedly incumbent upon each and all of us to train our fingers to the utmost of our power, yet, as was stated in Toronto, it is about as easy to gauge the arterial pressure by means of the fingers as to estimate the temperature by applying the hand to the skin. We can, it is true, learn a great deal, not only about the arterial walls, but about the general state of the circulation, by means of the educated finger, but no one, however skilful and experienced, can gauge the pressure. On the present occasion it does not fall within the scope of my remarks to discuss the various instruments which are in use in the estimation of arterial pressure; but you will allow me to say that, with the exception of the sphygmomanometers which employ the method of circular compression — obliterating the pulse in one of the larger arteries by means

of a broad cuff in communication with a mercurial manometer — all other instruments are only of historic interest. Amongst the instruments which are of real utility may be mentioned those of Riva Rocci, Martin, Cook, Stanton, Janeway, Erlanger, and myself. Amongst these there are only two which give graphic records—that of Erlanger and my own. Erlanger's instrument gives beautiful tracings of the oscillations of the column of air between the cuff and the column of mercury, but it in no wise gives any record of the height of the column of mercury by which the pressure may be estimated, and it is necessary to watch the manometer and note the oscillations of the mercury by means of the eye. My own instrument traces the movements of the column of mercury itself, and, by means of a transmission sphygmograph applied to the artery below the point of compression, it gives an absolute record of the height of the column at which the return of the pulse occurs—in other words, it graphically records the systolic pressure. Erlanger's instrument gives an approximation to the diastolic pressure; but here again it is necessary to read the height of the column of mercury and make a note of it, while, in my own instrument, the diastolic pressure, like the systolic, is graphically recorded.

Before we proceed to the consideration of the uses of the sphygmomanometer in disease, it is necessary to have clear conceptions of the limits of arterial pressure in healthy people. From my own observations, as well as from the results obtained by many reliable observers, the normal systolic pressure in healthy young adults may be stated as varying between the limits of 100 and 140 mm. of mercury, the most usual figures being from 120 to 130. The diastolic pressure varies between 70 and 100, the commonest limits being from 80 to 90. Certain variations in pressure must be regarded as normal, and, in considering that of any individual, these considerations have to be remembered.

There are, in the first place, daily fluctuations, resulting undoubtedly from many different influences, some of which are at present obscure. It may be stated that in general the pressure attains its maximum in the forenoon, after which it falls, commonly, however, manifesting another rise in the afternoon. These facts lead us to the conclusion that our readings must be taken at the same hour as far as possible. The influence of food is rather variable. A rise of pressure is sometimes found after a meal, but a fall takes place almost as commonly. The fall can easily be explained by the diversion of blood into the abdominal vessels; but as this is often compensated by reflex stimulation of the vasomotor system, the entrance of food may undoubtedly elevate the pressure. All readings of the pressure ought, therefore, to be taken in any individual with a definite relation to the administration of food. Posture has considerable effect on the pressure. A change from lying to sitting does not produce much effect, but

a great influence is exerted by the change from either of these positions to that of standing. It is the diastolic pressure which is mostly modified by this change of posture, and the pulse pressure limits are, therefore, lessened by the upright position. It is obvious that, when observing the arterial pressure of any individual, it should always be done in the same position. The effect of occupation upon the pressure is considerable, both as regards physical and mental exertion. It is therefore necessary to note with what the person under observation has been employed previous to making the observations. Those who lead lives requiring considerable exertion have, speaking generally, a higher pressure than those whose energy is not subject to such severe demands. It is accordingly needful to take into consideration in every case the occupation of the individual. We do not yet know to the full what influence is exerted by external temperature, but we know sufficient to be certain that when the individual under observation is subject to any departure from the normal external temperature, he is apt to show a rise of pressure. As yet we know very little about the effect of such articles as tea and coffee, but we know that alcohol, after a slight initial rise caused by acceleration of the heart, brings about a fall of arterial pressure. Tobacco, on the other hand, effects an increase of pressure by its influence on the vaso-constrictor apparatus, and, as has been more particularly observed in France, it leads to hyperpiesis. Both alcohol and tobacco lead in the long run to arterial sclerosis.

In our attempts to estimate the absolute value of arterial pressure, our investigations are surrounded by many limitations. These to a large extent consist in the difficulties attendant on the determination of the different factors maintaining the pressure. The relative amounts of energy and of resistance are still a sealed book. An absolutely low general blood pressure may be one which is relatively too high for the energy of the heart; while, on the other hand, a pressure which appears to be abnormally high may be one which is quite low in relation to the energy of the heart. The fact that arterial spasm, general or local, has an important influence in modifying the blood pressure, has always to be borne in mind; as a disturbing factor it may produce rapid changes in its level." These remarks made by me in the Toronto discussion sum up our chief difficulties in connection with the study of blood pressure.

To show clearly some of the practical results which flow from the study of arterial pressure, it will be most helpful to you if my remarks are confined to my own observations, from which you will allow me to select some examples both of acute and of chronic disease. Undoubtedly the most constant results in any of the acute infectious diseases are to be found in typhoid fever. In this disease the arterial pressure is

almost invariably low, the fall in pressure beginning towards the end of the first, or early in the second, week, and progressing steadily until convalescence is established. Unfortunately for my present purpose, it is only occasionally nowadays that typhoid fever comes under my own immediate observation, and it is therefore impossible for me to lay before you anything of value from personal experience. But the case is very different as regards pneumonia, which is rarely absent from my wards, and in which, therefore, abundant opportunities of observation have been afforded me. It is undoubtedly true that pneumonia has not such a

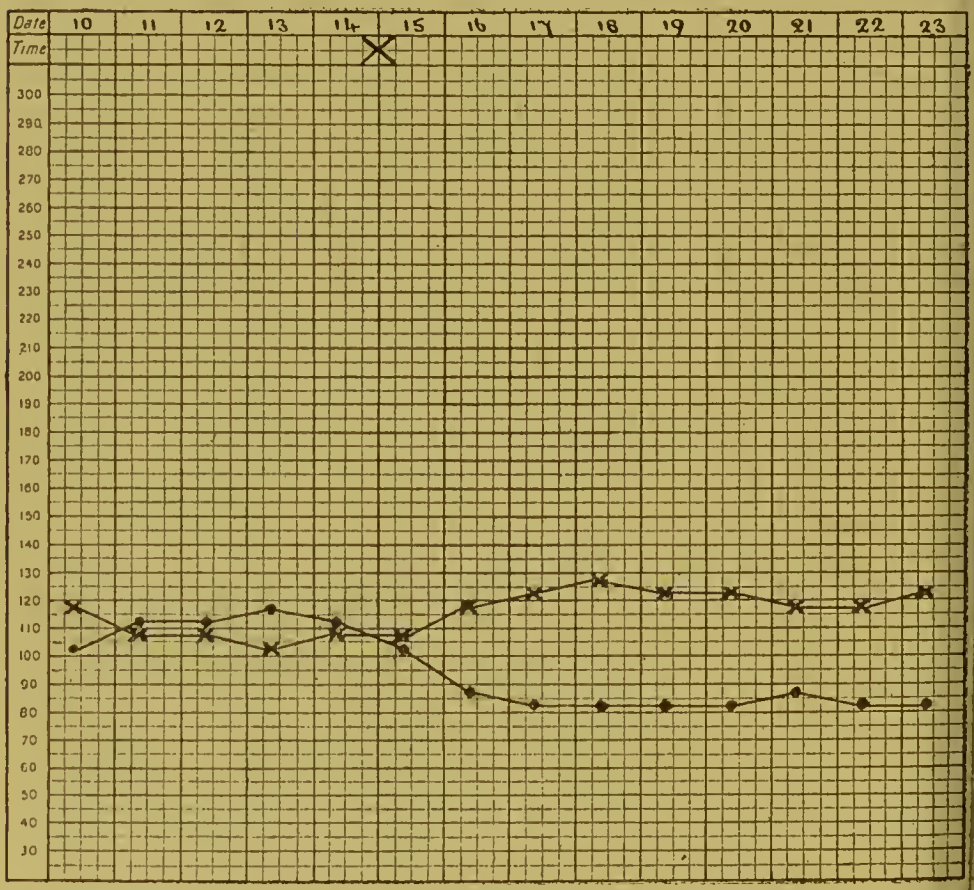

FIG. 1.—Chart of pulse rate and arterial pressure from a case of acute pneumonia. The crisis occurred between the evening of the 14th and morning of the 15th October, and was not accompanied by any fall of the pressure, although the rate of the pulse gradually sank. Daily record, about 11 a.m. The crosses give the pressure and the dots the rate in all the charts.

uniform effect on arterial pressure as is seen in typhoid fever, and the results of many different observers show extreme variations. It may be stated as a general rule that the pressure tends to be a little below normal, with considerable variations throughout the course of the disease. It has been asserted that there is a sudden fall at the period of the crisis; this, however, has certainly been far from common in my experience. A pressure appreci-

ably below the normal in pneumonia is invariably of evil omen, and any considerable fall bodes disaster. When the arterial pressure, expressed in millimetres of mercury, does not fall below the pulse rate, expressed in beats per minute, the fact may be taken as of excellent augury, while the converse is equally true. From the work of the last few years in my own wards no fact is more certain than this. It is illustrated in the charts, Fig. 1 and Fig. 2.

In the endocarditis of acute rheumatism the pressure is very often below the normal, but, as might readily be expected, there

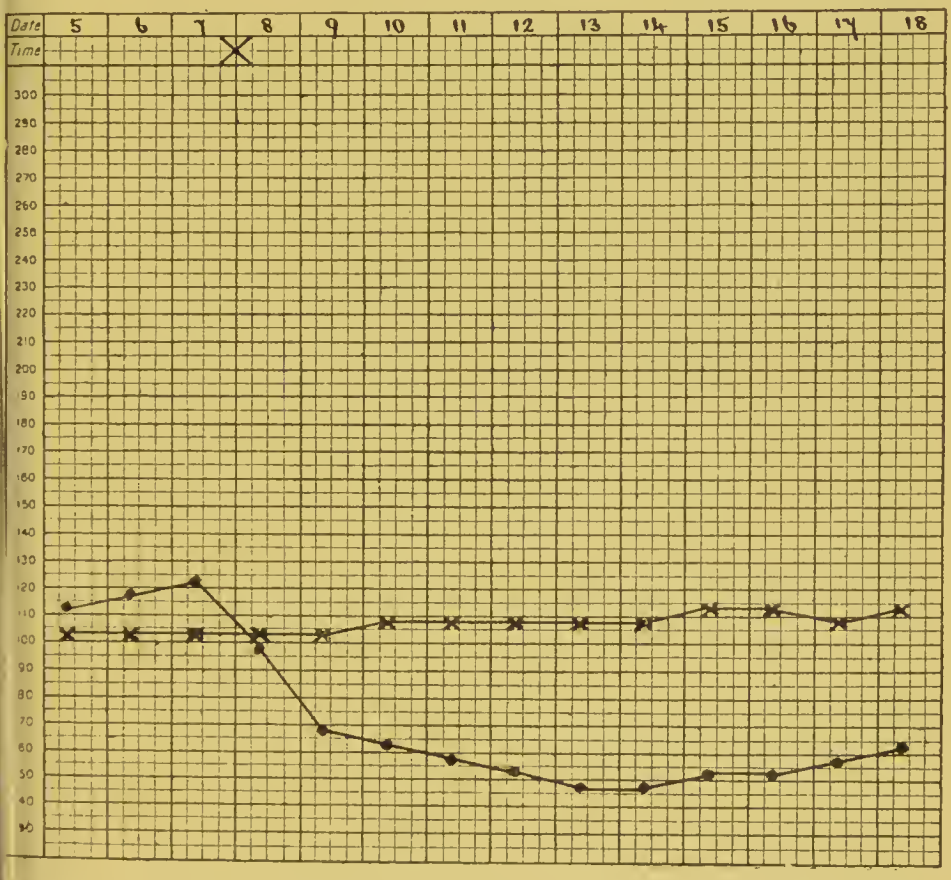

FIG. 2.—Chart of pulse rate and arterial pressure from a case of acute pneumonia. The crisis took place between the 7th and 8th October, with no change in pressure, but a great diminution of rate. Daily record, about 11 a.m.

are very considerable variations in it. There are not merely in this disease great fluctuations of temperature, which undoubtedly cause the variability of pressure in pneumonia, but the effects of the toxins upon the heart muscle, and the disturbances produced by the alterations in the cusps, have to be taken also into account. In this affection the more nearly the arterial pressure approximates to the normal the better is the outlook for the patient. A

good example of the range of pressure in endocarditis is given in Fig. 3. The arterial pressure in acute disease furnishes one of the most valuable guides in regard to prognosis, and the brief references to my observations which have been laid before you will, it is to be hoped, lead you to give some consideration to the subject.

When we turn to chronic affections we are confronted by a totally different series of conditions. Instead of rapid effects and swift changes, we meet with alterations of gradual, even of

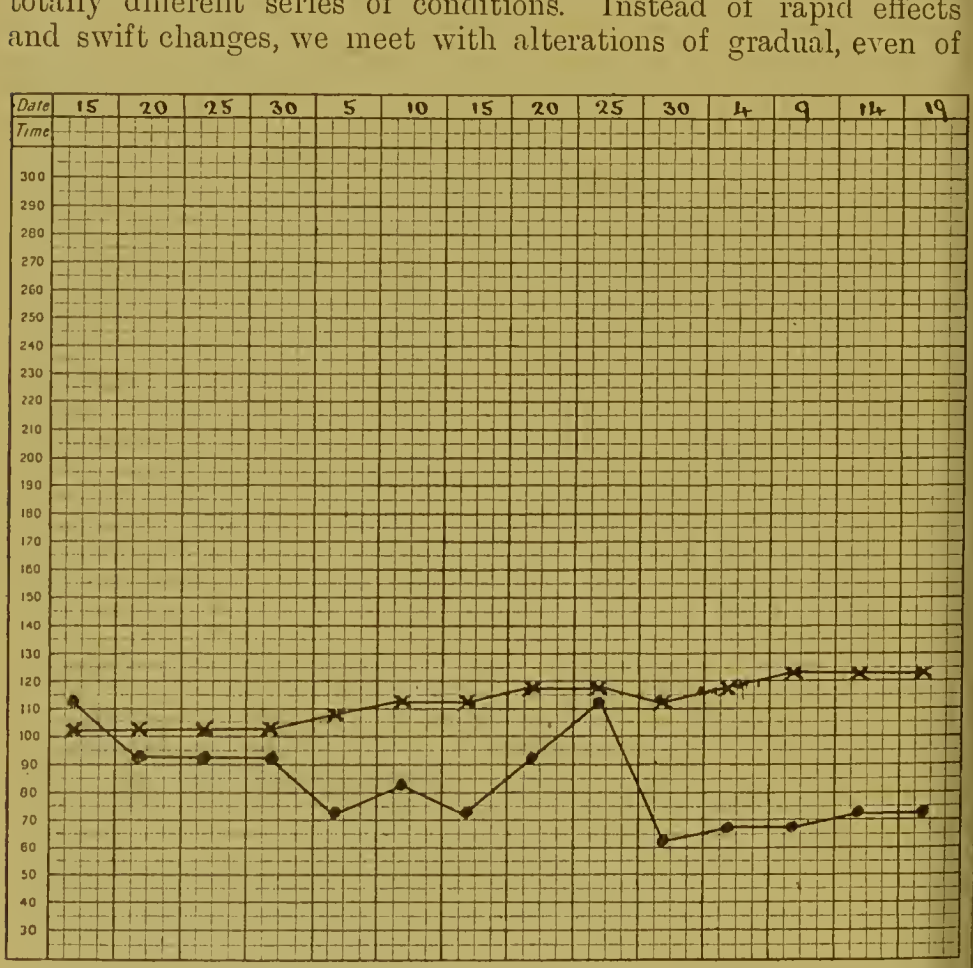

FIG. 3.—Chart of pulse rate and arterial pressure from a case of acute rheumatism with pericarditis and endocarditis. The steadiness of the curve showing the pressure readings is in strong contrast to that giving the pulse rate. The record gives the figures every fifth day at 11 a.m. from 15th June to 19th August.

insidious origin; of slow, perhaps of imperceptible development; of continuous, possibly of relentless persistence. Two such conditions may be mentioned, both of them taken from the heart. Aortic disease, implying both obstruction and regurgitation at the aortic orifice, presents one of the most striking examples of such affections; it is of great interest to find that in this disease the arterial pressure is of real value in prognosis and therapeutics. In some cases of this disease the systolic pressure is extremely

high, and the diastolic pressure remarkably low. Readings taken from cases under my own observation have frequently furnished a systolic pressure of 180 or 190, with a diastolic pressure of 70 or 80. On the other hand, in this disease it is quite common to find that the extremes are not so widely separated, and that the variation between maximum and minimum does not exceed 50 or 60. It must be obvious in these latter cases that the outlook for the patient is very much better than when the circulatory apparatus is subjected to enormous extremes of pressure. When the limits are very wide it is much more necessary to insist upon the avoidance of over-exertion than when the extremes are not widely separated. Taken in conjunction with the amount of cardiac hypertrophy and the characters of the arterial pulse, the blood pressure is, therefore, of extreme importance.

Another chronic condition which has lately attracted a great deal of my attention is that of heart-block, associated with bradycardia. Most of the cases which have been recently studied by me have manifested extreme infrequency of the pulse, as the result of a failure of conduction at the auriculo-ventricular junction, and in most of the cases it has been possible to prove that the auricles pulsated three or four times for each contraction of the ventricles. In some of these cases the systolic pressure has reached as high a level as 270, while the diastolic has been only 80. Undoubtedly, in some of these cases, conditions analogous to those of aortic disease have been present, inasmuch as the heart was hypertrophied and a large quantity of blood was ejected during each systole. Then, as the period of repose succeeding the cardiac diastole was enormously prolonged, the pressure was allowed to fall to a low level before the succeeding systole occurred. In this way, although from a totally different cause, extremely wide limits of pressure are produced.

Another series of conditions affecting blood pressure is to be found in alterations of the arterial walls. In the discussion of these conditions, however, we are brought face to face with such a complex group of causes, that it is often extremely difficult to come to any definite conclusion as to which is the principal factor in bringing about the morbid results. It is an extremely common experience to find arteries which are very thick in association with low pressure, while the converse is equally true that arteries which are in no respect thickened are found to be associated with high pressure. Such conditions are of necessity more common in advancing years, but they have met me frequently in those who are still young. General arterial sclerosis is, without doubt, usually associated with high pressure. In a large proportion of such cases the pressure is high, and the aortic second sound gives the musical ringing character so aptly termed by Potain the *bruit de tabourka*. But, on the other hand, a very obvious arterial degeneration may be associated with moderate or even

low pressure, which, at first sight, is a hard saying. It is probable that the observations of Hasenfeld and Hirsch furnish the explanation of many discrepancies. Unless the internal arteries have undergone sclerotic changes as well as the external, the pressure is not elevated. But, in other cases, where the aorta has undergone degeneration and has become dilated, and where the splanchnic vessels have become sclerotic, the pressure is usually much above the normal. A continuous

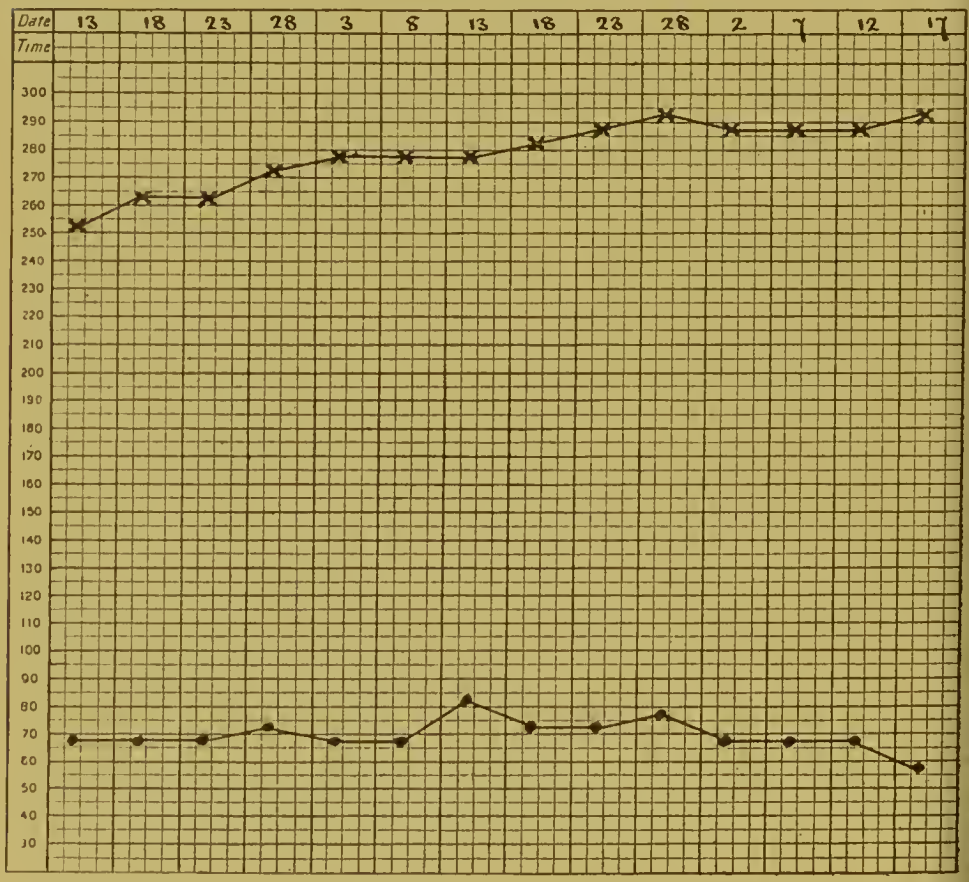

FIG. 4.—Chart of pulse rate and arterial pressure from a case of arterial sclerosis, cardiac hypertrophy, and interstitial nephritis. It shows a continuous high pressure in spite of all measures adopted. The record gives the figures every fifth day at 11 a.m. from 13th September to 17th November.

systolic pressure of about 300, with a diastolic pressure of about 230, is quite common.

The last illustration to be brought before you is that afforded by Bright's disease, and the type which will occupy our attention is chronic interstitial nephritis. Let me say, however, before entering upon this particular disease, that a great deal of the teaching which has been in vogue in regard to acute nephritis and certain forms of chronic nephritis has been based on observations

far too limited in their scope. The arterial pressure in acute nephritis has, in my own experience, frequently been subnormal, and it is, therefore, difficult to accept without reservation the conclusions which were urged a good many years ago by Mahomed. Again, in many cases of parenchymatous nephritis under my own observation, the pressure has frequently not been above the normal, which certainly leads to the conclusion that many factors must be at work in those cases which manifest an increase of

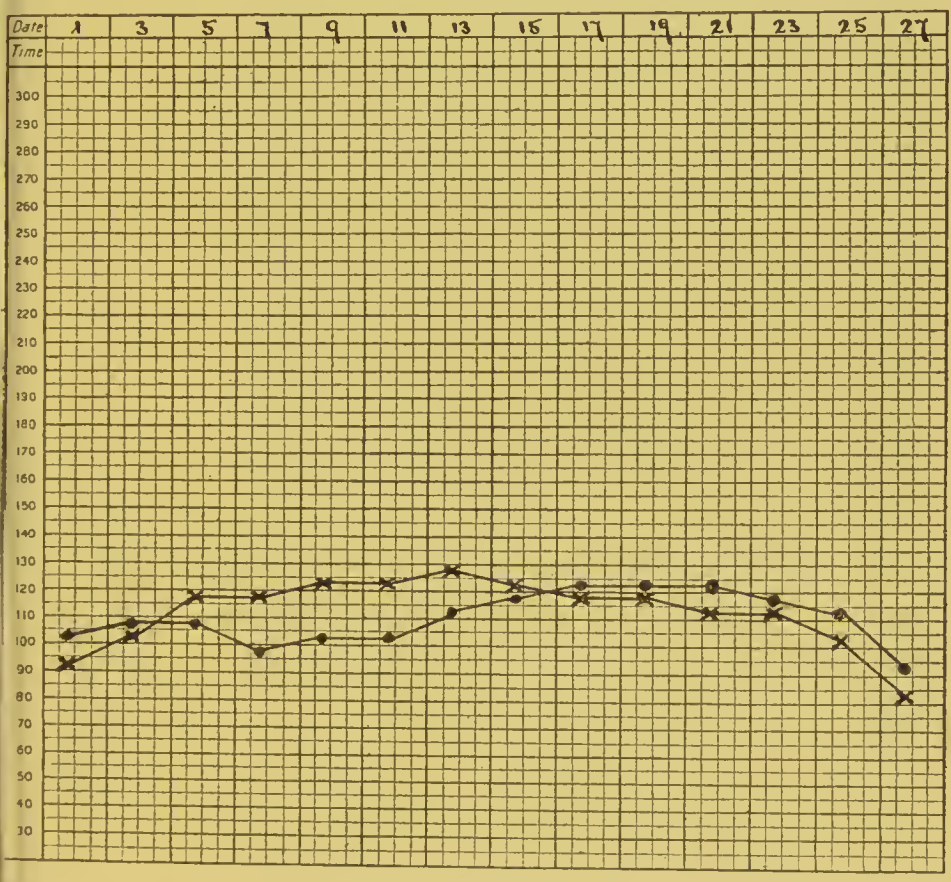

FIG. 5.—Chart of pulse rate and arterial pressure from a case of Addison's Disease. The employment of adrenalin caused a temporary rise of pressure, and later an increase of rate, but after a fortnight it ceased to produce these effects, and the patient gradually sank and died. The pressure is recorded every second day, taken about 11 a.m., from 1st to 27th October.

pressure. Interstitial nephritis is so commonly, if not invariably, associated with arterial sclerosis, that the two processes must be regarded as merely different aspects of a general disease, in which, however, there may be infinite varieties on account of the distribution of the principal changes. In this disease the pressure reaches the highest point attained in any chronic affection, and not infrequently this high pressure defies every effort at reduction. As illustrative of such a case Fig. 4 may be referred to. It gives the results of continuous observations on an elderly man in my

own wards, with general arterial selerosis, eardiac hypertrophy, albuminuria, and threatened attaeks both eerebral and eardiae. In spite of every means to lower the arterial pressure, ineluding veneseetion and all the nitrites, as well as eontinuous administration of the iodides, the pressure remained persistently high, beeause none of our therapeutie measures were able to influenee the arterial walls.

One last subjeet may reeeive brief attention in passing. In Addison's disease the arterial pressure is generally, but not invariably, low. It is probable that the varying results obtained in this affeetion are due to the respeetive implication of the eortieal and medullary portion of the suprarenal eapsules, the latter of whieh alone furnishes the pressor substanee. Cases under my eare have almost invariably given readings varying between 80 and 100 of systolie pressure. Lower readings have been observed by Stursberg and other workers. An interesting ehart from a reeent ease under my eharge in the Royal Infirmary is shown in Fig. 5. Under the influenee of adrenalin the blood pressure steadily rose and then began to sink, and the patient, towards the end of his life, had a blood pressure of about 80.

Enough has been said to show how mueh of seientific interest and of praetieal utility revolves around the subjeet of arterial pressure. There are many diffieult problems eonneeted with it, upon whieh, on this oeeasion, it is no part of my duty to dwell. With a group of faetors so numerous and so varied as those which control the arterial pressure, it ean be no matter for surprise that there is eonsiderable diversity of opinion in respeet of some of its aspeets. As regards the elinieal investigation and therapeutie indieations furnished by its study, there are still many matters requiring elueidation, and it seems to me that our ehief hope for the solution of the diffieulties surrounding the subjeet must be in the eolleetion of a large number of faets by eompetent observers. Even with a great group of sueh observations there may still be eertain diserepant opinions on some of the more knotty points, sinee we fortunately do not look at every subjeet from the same point of view,

"And minds are many, though truth be one."